Phase Change Material for Temperature Control of Imager or Sounder on GOES Type Satellites in GEO

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This paper uses phase change material (PCM) in the scan cavity of an imager or sounder on satellites in geostationary orbit (GEO) to maintain the telescope temperature stable. When sunlight enters the scan aperture, solar heating causes the PCM to melt. When sunlight stops entering the scan aperture, the PCM releases the thermal energy stored to keep the components in the telescope warm. It has no moving parts or bimetallic springs. It reduces heater power required to make up the heat lost by radiation to space through the aperture. It is an attractive thermal control option to a radiator with a louver and a sunshade.

Nomenclature

C	=	carbon
H	=	hydrogen
GEO	=	geostationary orbit
GOES	=	Geostationary Operational Environmental Satellite
PCM	=	phase change material

I. Introduction

AN imager or sounder on satellites, such as the Geostationary Operational Environmental Satellite (GOES), in GEO has a scan mirror and scan motor in the scan cavity. The GEO orbit has a 35,748 km altitude and a 0º inclination. The orbit period is 24 hours. During part of the orbit, direct sunlight enters the scan aperture and adds heat to components in the scan cavity. Solar heating increases the temperatures of the scan mirror, scan motor, primary mirror and secondary mirror. Overheating of the scan motor could reduce its reliability. The GOES-H imager scan mirror temperature was as much as 67 ˚C when sunlight entered its scan cavity (Figures 1 and 2). GOES-I had pitch maneuvers to prevent overheating[1,2]**.** For GOES-N to P, a radiator with a thermal louver rejects the solar heat absorbed to keep the scan cavity cool. A sunshield shields the radiator/louver from the Sun[2,3] (Figures 3 and 4). For the remainder of the orbit, sunlight does not enter the scan aperture. The scan cavity radiates heat to space through the scan aperture. Also the radiator/louver continues radiating heat to space because the louver effective emittance is about 0.12, even if the louver is fully closed[3]. This requires makeup heater power to maintain the temperature within the stability range.

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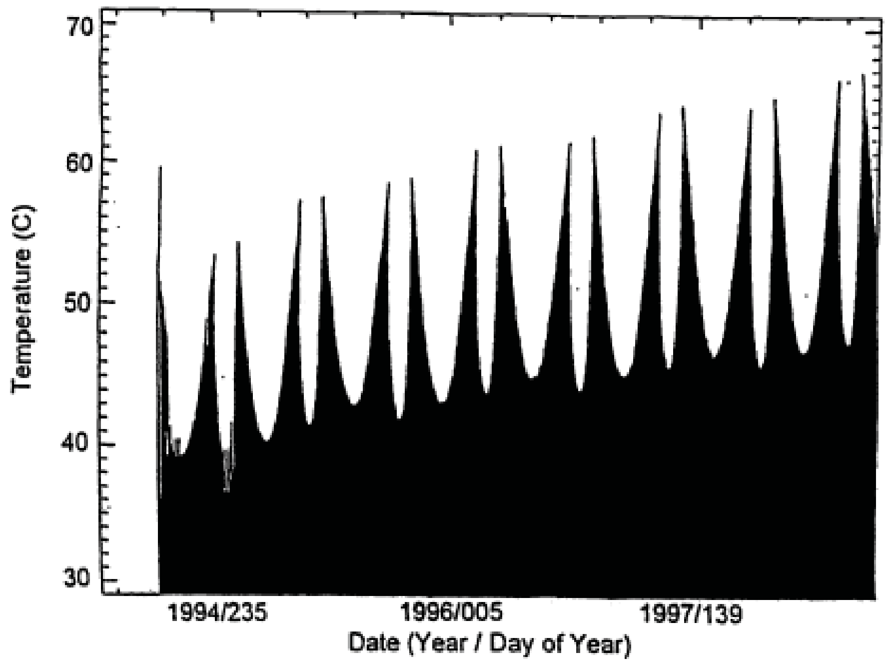

Figure 1. GOES-H Imager Scan Mirror Flight Temperature.

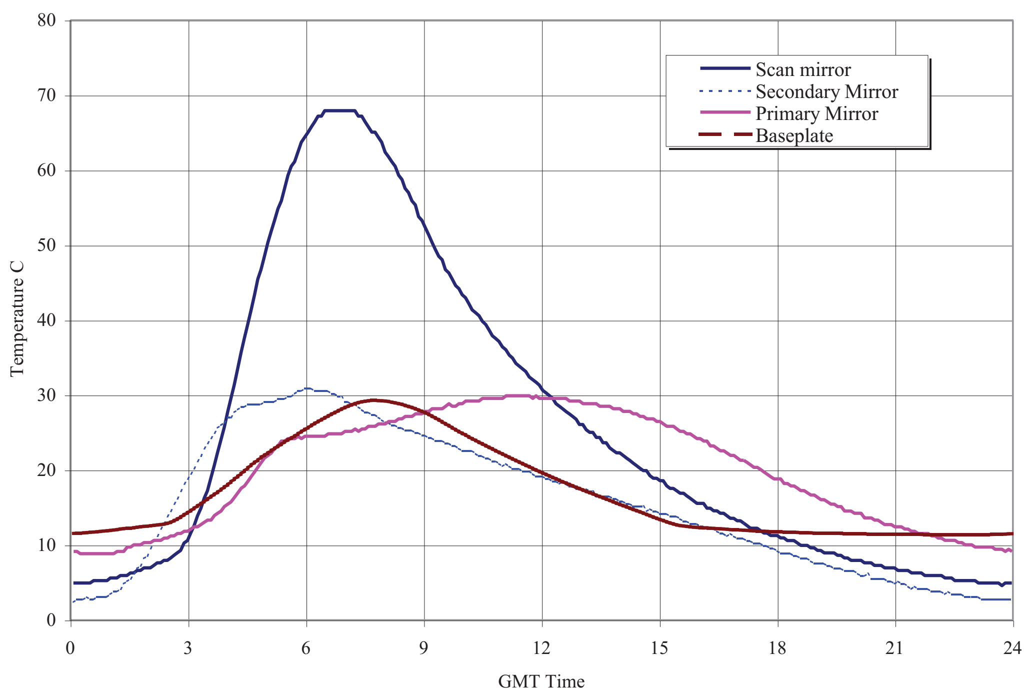

Figure 2. GOES-H Imager Scan Cavity Flight Temperature.

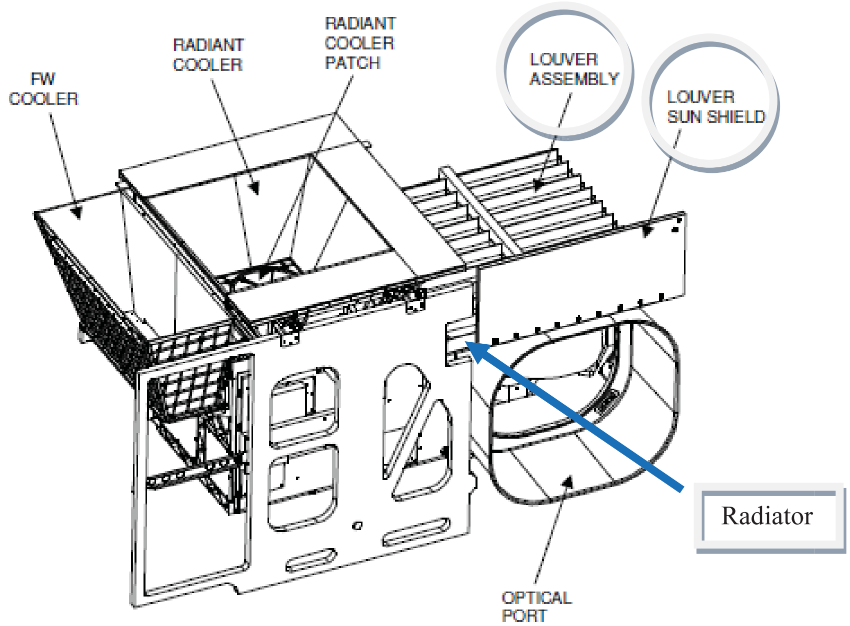

Figure 3. GOES-N to P Imager Radiator, Louver and Sunshield.

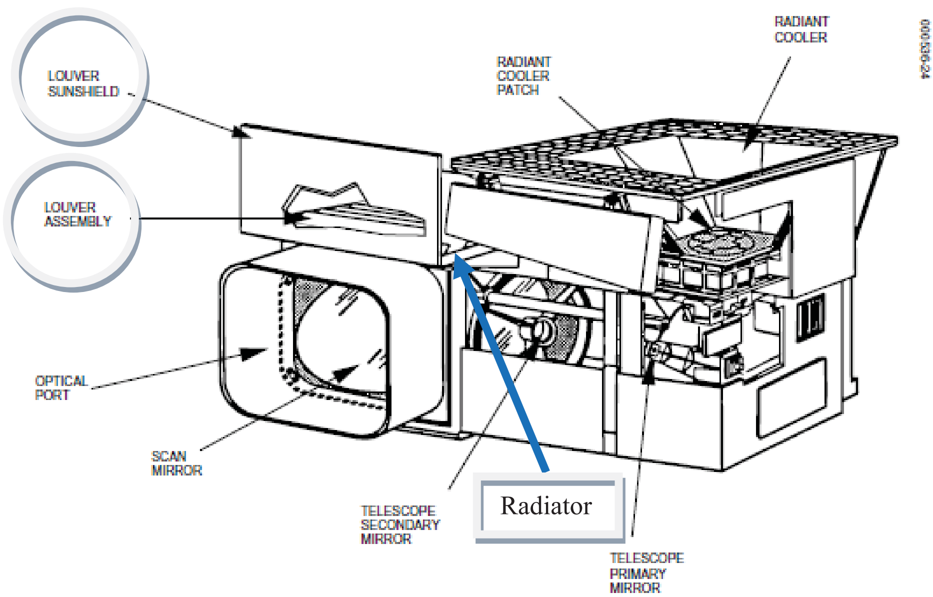

Figure 4. GOES-N to P Sounder Radiator, Louver and Sunshield.

II. Objective

The objective of this paper is to present a thermal control concept of using PCM in the scan cavity of an imager or sounder on a satellite in GEO to maintain the temperature stability of the scan mirror, scan motor, primary mirror and secondary mirror.

III. Thermal Concept of Using PCM in Scan Cavity

The thermal concept of using PCM in the imager or sounder scan cavity in GEO is as follows. Phase change of PCM occurs at a constant temperature. When sunlight enters the scan aperture, solar heating causes the PCM to melt. When sunlight stops entering the scan aperture, the PCM releases the thermal energy stored to keep the

components in the scan cavity warm. It reduces the heater power required to make up the heat lost by radiation to space through the aperture. It has no moving parts or bimetallic springs. PCM is compact because it has a high solid-to-liquid enthalpy. Also, it could be spread out in the scan cavity. These are advantages when compared to a radiator with a louver and a sunshade.

Paraffin waxes, which have a carbon number from 14 to 19, provide a melting point in the 6˚C to 32˚C range[4-7] (Figure 5) used in the thermal control concept presented in this paper. For even carbon numbers, 14, 16 and 18, the solid-to-liquid enthalpy is about 230 to 250 kJ/kg (Figure 6).[4-7] Typically paraffin PCM is encapsulated in aluminum shells. The ratio of mass of paraffin to mass of aluminum shell is typically 2:1.[7] Paraffin PCM has spaceflight heritage. Figure 7 shows a paraffin pack flown on an instrument in the NASA MESSENGER mission to Mercury. The technology readiness level (TRL) of paraffin PCM for spaceflight is at least 6.

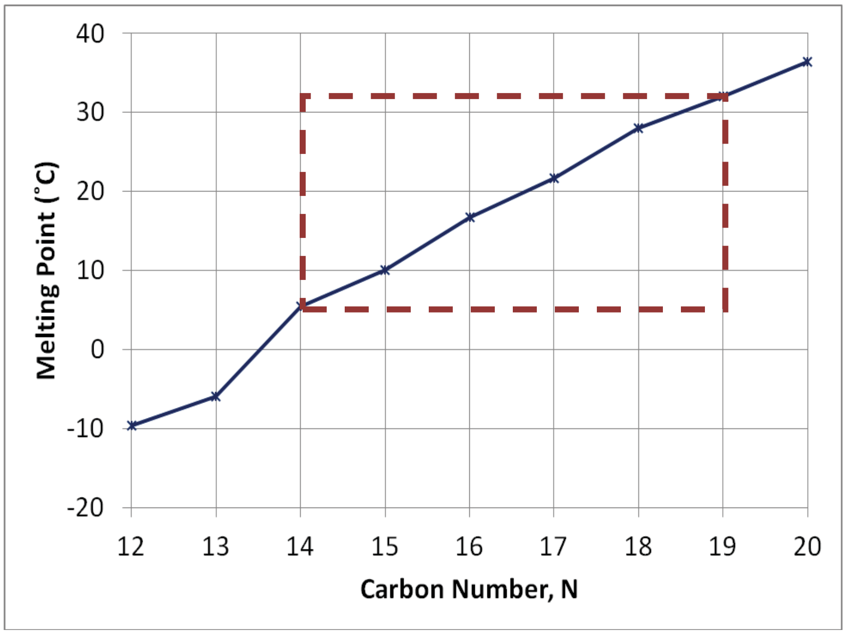

Figure 5. Melting Point of Paraffin (C_NH_{2N+2}).

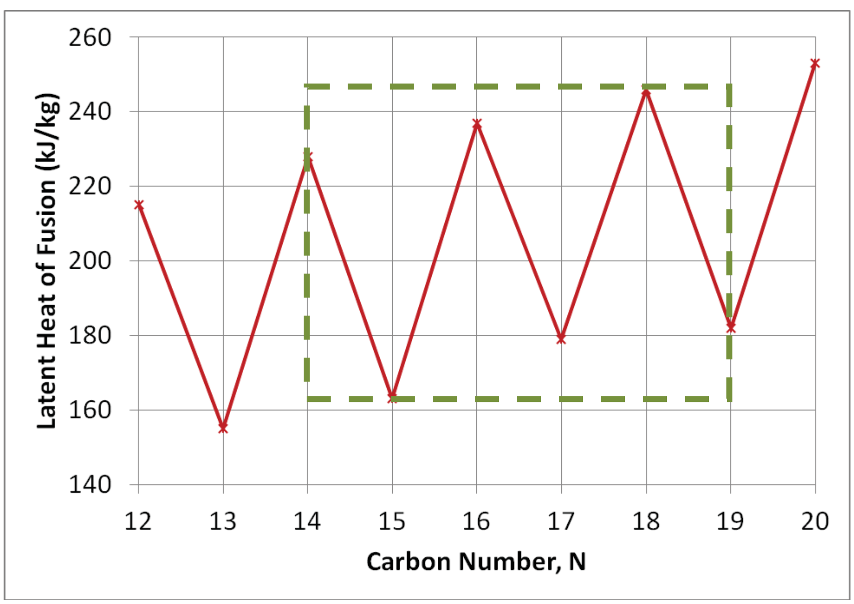

Figure 6. Latent Heat of Fusion of Paraffin (C_NH_{2N+2}).

Figure 7. Paraffin Packs Flown on an Instrument in MESSENGER Mission.

IV. Case Study for PCM in Scan Cavity in GEO

A case study of using paraffin PCM for thermal control of the GOES sounder scan cavity and scan mirror is presented. Figure 8 shows the orbital thermal model with the GOES satellite in GEO. Figure 9 presents the solar flux absorbed by the scan cavity and scan mirror versus orbit time. The total solar flux absorbed by the scan cavity and scan mirror is approximately 3,820 kJ per orbit. If octadecane ($C_{18}H_{38}$) with a 28°C melting point is used, for example, approximately 15 kg is required. When sunlight stops entering the scan cavity, the paraffin PCM begins to freeze due to heat radiation from the scan cavity to space through the aperture. Just prior to sunlight entering the scan cavity in the next orbit, all the solar energy stored in the paraffin PCM has been released. The paraffin PCM "melt-and-freeze" cycle repeats in each orbit. The mass of aluminum shell required to encapsulate the paraffin is approximately 7.5 kg.

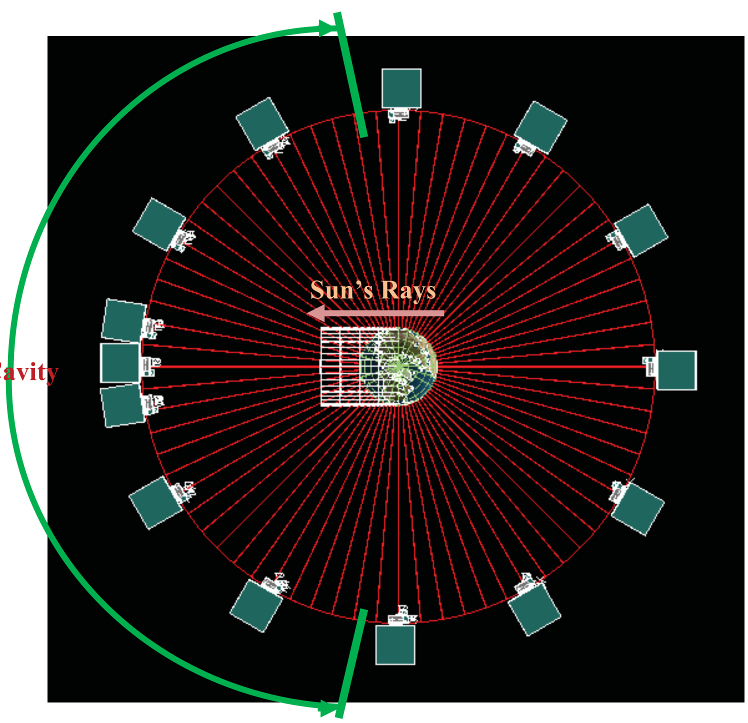

Figure 8. Satellite with Imager or Sounder Nadir Pointing in GEO .

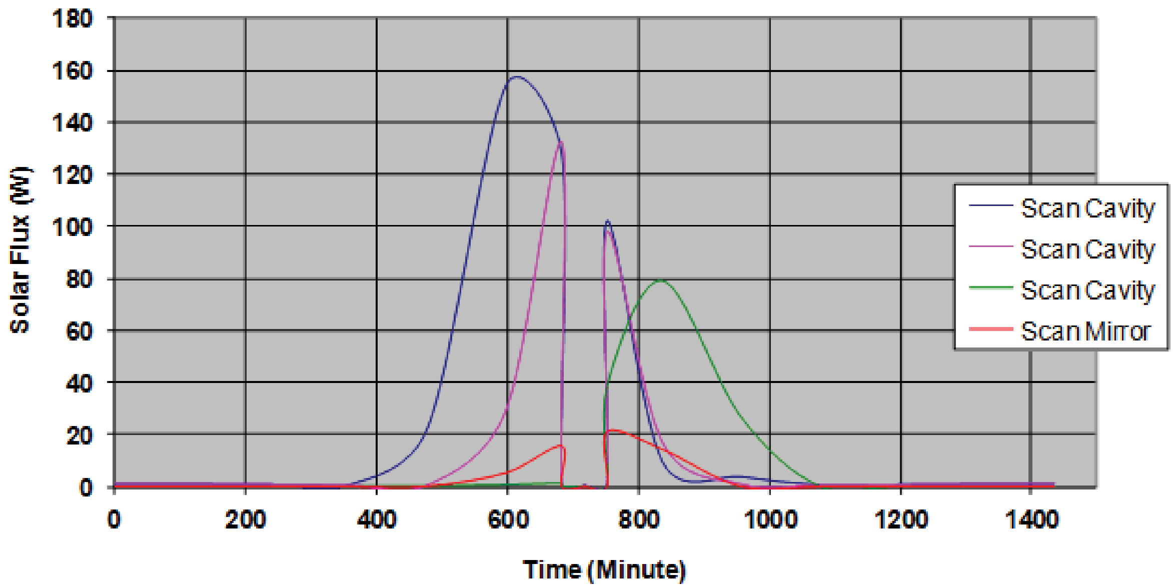

Figure 9. Solar Flux Absorbed by Scan Cavity and Scan Mirror in Orbit.

Paraffin PCM can be attached to the telescope baseplate, scan support plate, housing panels and backside of scan mirror to increase the telescope thermal stability (Figure 10).

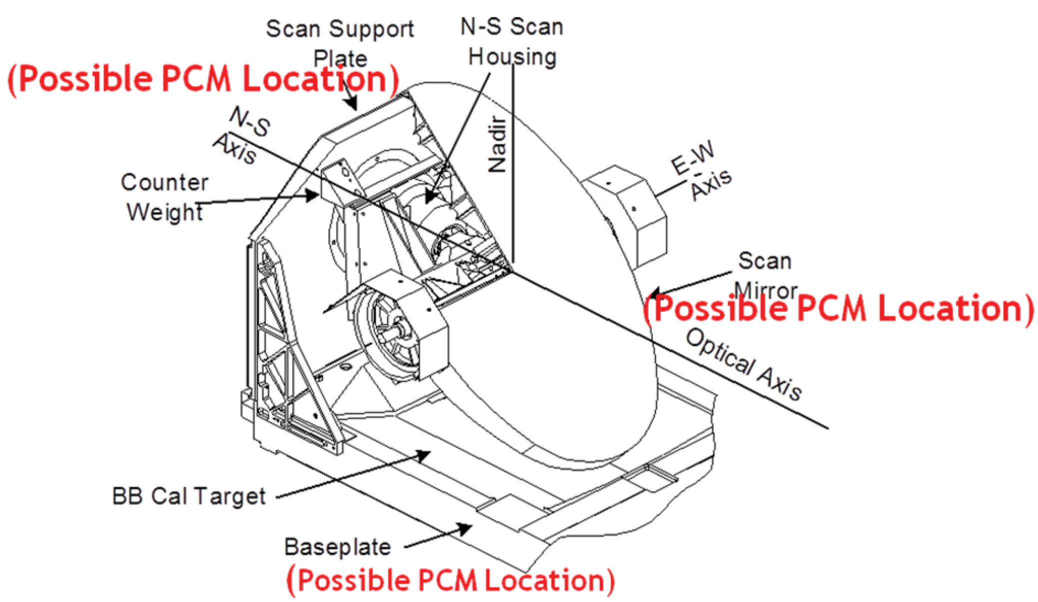

Figure 10. Possible PCM Locations.

V. Conclusion

Paraffin PCM can be used to maintain thermal stability of an imager or sounder on satellites, such as GOES, in GEO. When sunlight enters the scan cavity, the PCM stores the heat at a constant temperature. When sunlight stops entering the scan cavity, the PCM releases the heat at a constant temperature. The PCM can be attached to different components in the telescope. It reduces heater power. It is an attractive thermal control option to a radiator with a thermal louver and a sunshade.

References

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